Air-sea ammonia flux – a comparison of high and low latitudes

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surface ocean solas lower atmosphere study

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Presented here is data collected by our group over the past decade, which is currently in preparation for publication (Johnson *et al,* 2007a). Previous studies (Figure 1) have demonstrated a consistent marine ammonia source in the open ocean, which has been supported by evidence from isotope studies (Jickells *et al,* 2003) and corroborates the suggestion that in pre-industrial times the ocean fertilised the land with reduced nitrogen (e.g. Duce *et al.,* 1991).

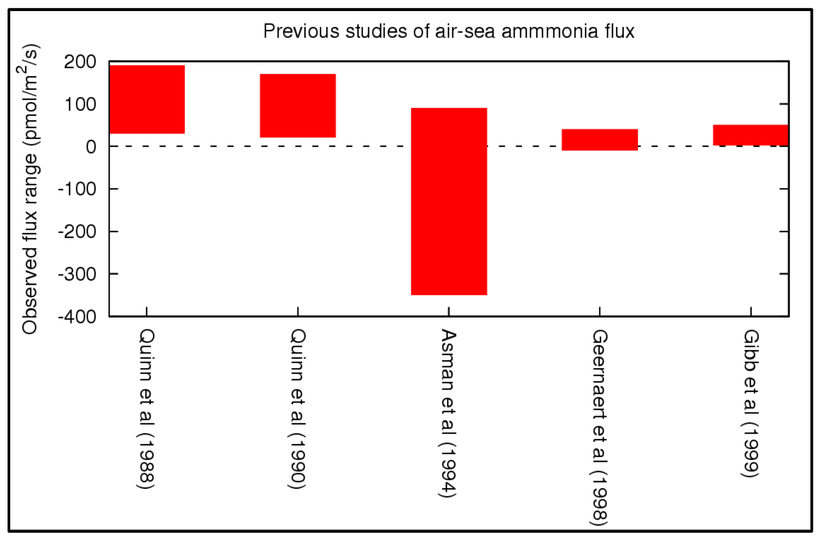

Figure 1. Previous studies of air-sea ammonia flux indicate a marine source (with the exception of the highly terrestrially influenced southern North Sea in Asman *et al,* 1994).

However, our data from high latitudes (Figure 2) indicates that fluxes out of the ocean at >50°N are rare, even in periods of highly elevated surface seawater concentration (up to 1uM during cruise JR75 - due to biological productivity - see Johnson *et al,* 2007b). We have identified that the reason for this is temperature.

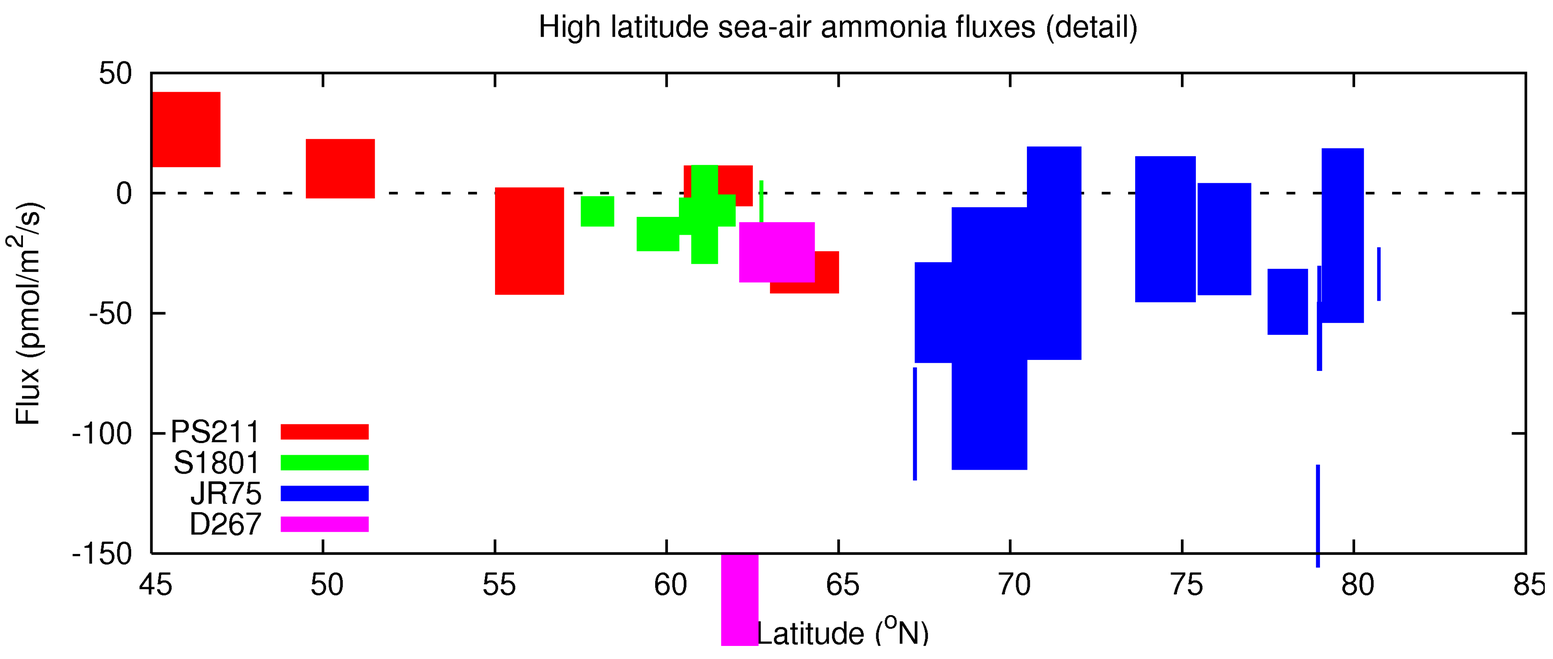

Figure 2. Air-sea ammonia fluxes measured by concentration difference during 4 high latitude cruises in the NE Atlantic and adjacent seas: PS211 - RV Poseidon, Reykjavik to Lisbon, autumn 1995; S1801 – RV Scotia, Northern North Sea survey, winter 2001; JR75 – RRS James Clark Ross, Norwegian Sea and Arctic Ocean, Spring 2002; D267 – RRS Discovery, Irminger Basin, Winter 2002. Note that the flux ranges from cruise S1801 and JR75 that overlap the zero flux line do so due to the gas phase concentrations being below the detection limit of the method (i.e. min concentration assumed for flux calculation = 0) and as such probably do not represent real upward fluxes.

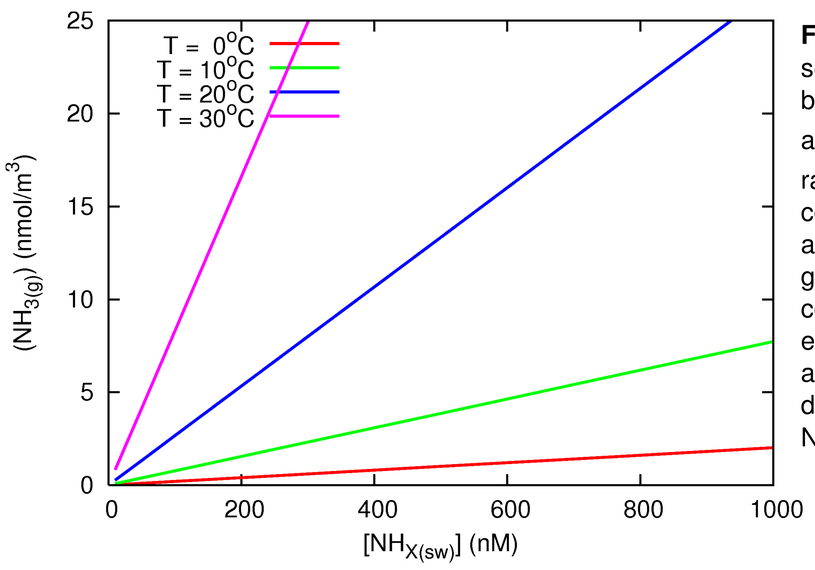

Figure 3. Temperature sensitivity of the equilibrium between seawater NH_X and atmospheric NH_3 over the range of concentrations commonly observed in the atmosphere and ocean. This graph represents the combination of Henry's law equilibrium between gas and aqueous phases and the acid dissociation of ammonium. i.e. $NH_{4\ (sw)}^{+}$ <-> $NH_{3(sw)}$ <-> $NH_{3(g)}$

The temperature sensitivity of the equilibrium between seawater ammonium and gas phase ammonia (Figure 3) is such that it is very difficult to drive a flux out of the ocean at environmental concentrations at low T. Conversely it is difficult to drive a downward flux at high temperature. This is highlighted in our data from the Atlantic Meridional Transect cruise AMT17 where, in spite of extremely low surface seawater NH_X concentrations (2 – 20 nM) in the N and S Atlantic oligotropic gyres, observed fluxes were predominantly out of the ocean (Figure 4).

This finding has important implications for our understanding of the air-sea exchange of ammonia and other soluble trace gases – it appears that many biogenic gases will be unable to escape from the ocean at high latitudes where even a low background concentration in the marine boundary layer will inhibit a sea-to-air flux. In the case of ammonia this is potentially important for atmospheric neutralisation reactions and particle formation.

References:

Asman *et al.* (1994). Estimation of the net air-sea flux of ammonia over the Southern Bight of the North Sea. *Atmospheric Environment,* 28: 3647-3654.
Jickells *et al.* (2003). Isotopic evidence for a marine ammonia source. *GRL* 30: 1374
Johnson *et al* (2007a).Field observations of the ocean-atmosphere exchange of ammonia – a comparison of high and low latitudes. *Global Biogeochemical Cycles*, in preparation
Johnson *et al* (2007b). Ammonium accumulation during a silicate-limited diatom bloom indicates the potential for ammonia emission events. *Marine Chemistry*, in press.
Geernaert *et al.* (1998) Fluxes of soluble gases in the marine atmosphere surface layer. *Tellus B*, 50, 111-127
Gibb *et al.* (1999) Ocean-atmosphere exchange and atmospheric speciation of ammonia and methylamines in the region of the NW Arabian Sea. *Global Biogeochemical Cycles,* 13, 161-178
Quinn *et al* (1990). Interactions between the Sulfur and Reduced Nitrogen Cycles Over the Central Pacific Ocean. *Journal of Geophysical Research* 95(D10): 16405-16416.
Quinn *et al.* (1988). Simultaneous observations of ammonia in the atmosphere and ocean. *Nature* 335: 336-338.

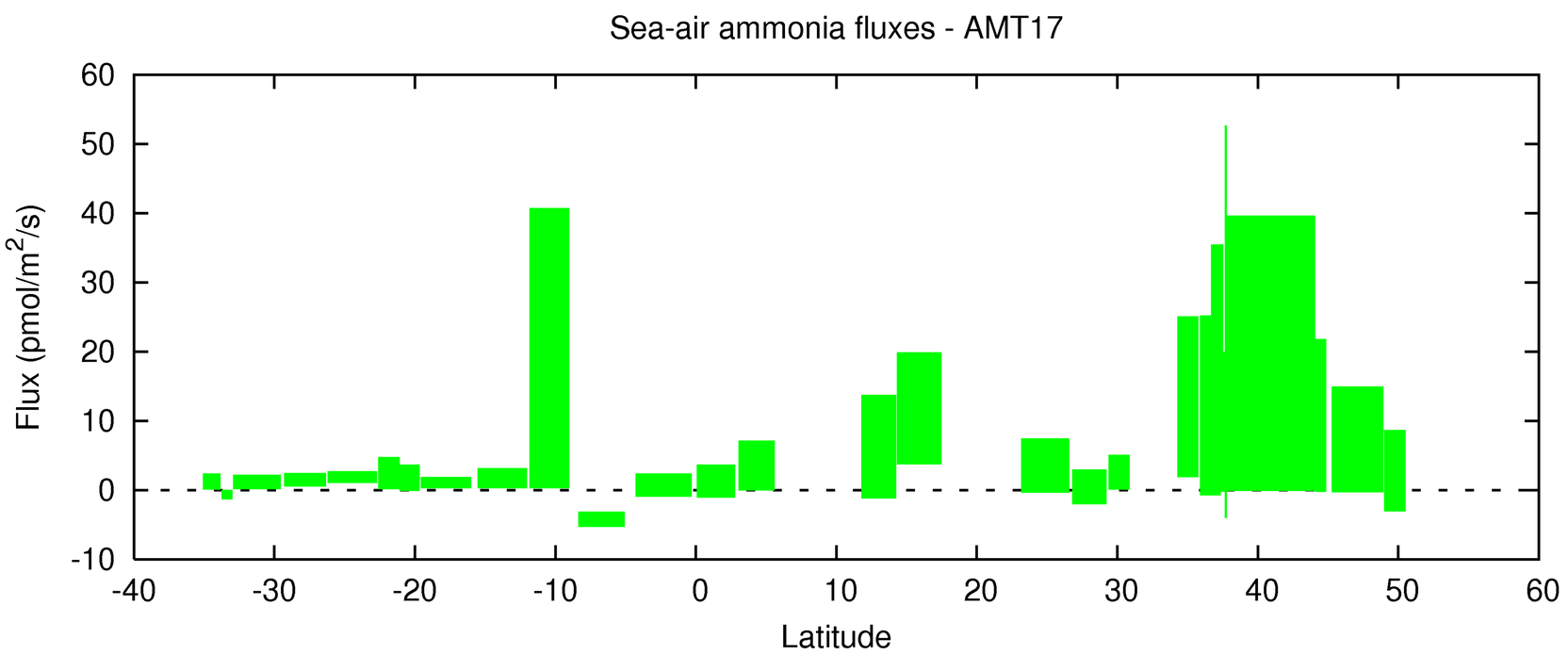

Figure 4. Air-sea ammonia fluxes measured during cruise AMT17 (RRS Discovery, October-November 2005, UK – Capetown).